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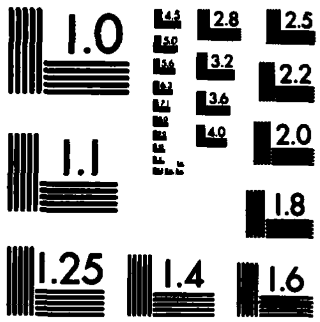
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# AVIONICS INTEGRITY PROGRAM (AVIP) - VOLUME IV

## Force Management - Economic Life Considerations


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AERONAUTICAL SYSTEMS DIVISION
AVIONICS INTEGRITY PROGRAM OFFICE
DIRECTORATE OF AVIONICS ENGINEERING
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This technical report has been reviewed and is approved for publication.

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The study assesses the qualities that define the "economic life" of avionic hardware. "Economic life" is the term often used to refer to the period of time during which financial considerations justify the continued use of an existing system. The study addresses the strategies of logistic support. Terminology for the development of one economic life model computer program is included in the appendix. It is incomplete. It provides a baseline for future work for evaluating the timeframe limits for determining whether continued use of or replacement of an existing system would be more cost effective.

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VOLUME IV: Economic Life

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# FOREWORD

This report is one of a series of four prepared for the Avionics Integrity Program Office, Wright-Patterson Air Force Base, Ohio. The reports address techniques and historical data (lessons learned) for enhancing the service life of avionic systems. The reports include contractor efforts between September 1983 and March 1984.

Each report represents a completed study in a specific area and stands alone. However, the contents of the four reports are meant to complement each other and they should be considered as the output of a single study aimed at determining those issues which contribute to the avionics integrity of military systems.

The titles of the remaining reports and their respective technical report numbers are provided as follows:

> ASD-TR-84-5009, AVIONICS INTEGRITY PROGRAM (AVIP) STUDIES: Program Cost Assessment - Environmental Stress Screening and Diagnostic Techniques, Volume III
>
> ASD-TR-84-5010, AVIONICS INTEGRITY PROGRAM (AVIP) STUDIES: Volume I, Procurement Phase Issues - Design, Manufacturing, and Integration
>
> ASD-TR-84-5011, AVIONICS INTEGRITY PROGRAM (AVIP) STUDIES: Hardware Case Studies, Volume II

These reports have been entered into the DTIC/NTIS system. Contact the Avionics Integrity Program focal point ((513)255-3369) to obtain the appropriate report number for ordering.

The authors wish to acknowledge the cooperation and consideration afforded to them by Mr. Thomas Dickman, Mr. John Kaufhold, and Major Lee Cheshire of the Avionics Integrity Program Office during the conduct of these studies. Without their continuing guidance and interest, these reports could not have been developed. The authors would also like to thank Mr. Tom Dolash, Mr. Keith Broerman, Susan Hendershot, Nanci Peterson, and the Text Processing Center personnel at Battelle Columbus Laboratories for their contribution to these reports.

# 1.0 ECONOMIC LIFE

## 1.1 Introduction

In the past, the USAF has experienced large increases in support costs over the budgeted costs for avionics systems. This is attributed to increased parts/spares cost for avionics systems as they progress through their life cycle. The support costs incurred by the USAF for the F-111 are a prime example. Increased support costs may be a function of system design, parts selection, reduced availability of parts, materials cost, changes in the operational environment, or a variety of other factors.

Regardless of the cause, the USAF is seeking the development of methods to avoid and/or reduce the probability of incurring unacceptable system support costs in the future. One such method under consideration for development would be used to project and identify the time at which system support costs reach an unacceptable rate. Identification of this point will provide the USAF with the information necessary to take timely corrective actions to eliminate or reduce the increasing support costs projected to occur for avionics systems. Ideally, a methodology such as this could be used in contractual as well as management processes. Contractually, the methodology would be used by the USAF as a parameter by which to compare the merits of prospective contractors. Ultimately, it would play a role in the awarding of the contract. As a management tool, the methodology would be used by the USAF to compare various technological opportunities. It would also provide management with the ability to identify decision points/break points for current and projected system designs; thus aiding management in their planning functions for acquiring, sustaining and replacing systems.

One such methodology envisioned as a possible solution to this problem and addressed in this volume (Volume IV) of the Avionics Integrity Report is the concept of economic life. "Economic life" is a term commonly used to refer to the period of time during which financial considerations justify the selection or continued use of a system. A variety of definitions currently exist for economic life. One definition of economic life is the period of time during which a system provides positive benefit. This definition is a very broad one and is dependent on the user's definition of "positive benefit". This may include benefits outside the realm of quantitative economic measures, such as mission life, physical life, and technological life, as well as qualitative benefits which are difficult to assess. To eliminate the difficulties encountered with this definition and to provide a definition more attuned to the contractual and management uses stated above, this report restricts economic life to address only those quantitative costs related to the economics of the life cycle cost of avionics systems. It addresses a much more narrow and explicit view of economic life than that of the preceding definition. It is preferable to define the period of time during which a system provides positive benefit as the "useful life" of a system. It is appropriate for the definition of the useful life of a system to consider all aspects and parameters involved in providing positive benefits as well as burdens to a system. Hence, only the assessment of a system's useful life, of which economic life is included, results in the decision

criteria necessary to make decisions with respect to initial implementation of a new system, continued or terminated operation of a current system and/or implementation of a proposed replacement system.

The remainder of this report discusses the definition of economic life, the use of life cycle cost models, and the issues surrounding contractual and management economic life measures. Also, conclusions and recommendations pertaining to economic life issues and measures are presented.

## 1.2 Towards a Definition of Economic Life

The concept of the economic life of a system includes the development, acquisition, and operating and support costs (i.e., the life cycle costs) of the systems. It also includes the idea of comparing the system against alternative systems. Combining these ideas gives the following candidate definition:

> The economic life of a system is the period of time during which the annualized present value of the remaining life cycle cost of the subject system remains lower than the annualized present value of the life cycle cost of all feasible alternatives which provide the same functional performance.

The annualized present value measure is used to allow comparison of systems with different lifetimes.

Several difficulties exist with the candidate definition. First, the computation of the life cycle cost of a system requires that the life of the system be known or very carefully approximated. This difficulty, however, possibly could be addressed through sensitivity analyses on "system life", for the life cycle cost computations, by selecting "target" ranges of system life and evaluating the resultant model data to determine "optimum" number of years of life for the system.

A second difficulty is the comparison of the subject system with all feasible alternative systems. For economic comparisions, the alternatives are constrained to have the same functional performance. Even so, the number of alternatives could be large.

Finally, meaningful predictions must account for changes in cost factors and technology. For example, the unit costs for replacement parts could rise in the later years of a system's life because of availability problems. Advances in technologies, such as VHSIC, could result in reduced cost factors for an alternate system.

In spite of its practical difficulties, the above candidate definition highlights several key ingredients of economic life. The next paragraphs attempt to express economic life as a function of system characteristics and parameters.

The economic life of an avionics system will depend on the costs of the subject system and the costs of alternative systems. These costs will depend on the complexity of the function performed, the technologies used, the nature of the parts used (standard or customized), the quality of parts selected, the methods of assembly, and the degree to which the design satisfies the identified operational and environmental stresses. Costs will also depend on the nature of the repair system (e.g., two levels or three levels), the way the system (LRU/SRU) is processed by the repair system (e.g., a system whose repair is relatively labor intensive would be affected more by increase in labor rates), and the relative costs of available alternative systems.

Assuming a fixed usage rate, the economic life of a system can be written as a function of numerous factors:

Economic life = F (system complexity, environmental factor, parts selection, architecture, physical life, technologies, physical stresses, repair characteristics, alternatives, ...).

Variations on this function could be written by changing some of the factors on the right-hand-side. In addition, more comprehensive or more detailed terms could be used, as long as they reflect the true factors that determine the costs of the subject system and its alternatives. The above factors were chosen since they seem to reflect system characteristics that may be directly related to economic life.

Physical life has been included in this expression for economic life since the end of the physical life of an element would signify the end of its economic life. It can be applied at various levels, from the entire system down to the piece parts. It must be taken into consideration that physical life may be of different degrees of importance for different types of parts. For example, it may be very important for electromechanical parts or parts exposed to a high-corrosion environment.

The concept of physical life is especially important in light of the increasing use of large-scale dual-in-line-package (DIP) integrated circuits (ICs), leadless chip carriers (LCCs), and multilayer printed circuit boards (PCBs) in the design and implementation of the current and next generation avionics system. Each of these new technologies has allowed the implementation of more complex tasks and sophisticated processing to be performed within the context of a more densely packaged LRS or SRU environment. The designers, however, have not always properly considered either the physical properties of the new devices or the environment in which the devices are expected to perform their intended function; which, in turn, has resulted in shortened life of the product due to thermal or vibration induced fatigue. For example, in the case of leadless chip carriers, the designer must be aware of the differing thermal coefficients of expansion (TCEs) between the multilayer PCBs and the leadless chip carriers that cause strains to be induced in the solder joints that bond the two together. Or in the case of the use of large-scale DIP ICs, the designer must be aware of the flexing/failing modes of the multilayer PCBs in differing random vibration environments, due to the fact

that if the IC is not located properly, large displacements of the PCB can cause the IC to undergo physical or electrical strain (and therefore failure).

An increasingly large body of literature is becoming available which points out these potential areas of failure that can be demonstrated to exist in today's complex avionic systems. In addition to describing the problem, these reports and studies have also formulated models and equations which not only describe the various behaviors, but provide a means for estimating the effects of the various physical and environmental stresses and strains that the SRU or LRU may be expected to encounter during its physical and economic life. These models and equations, when used in conjunction with knowledge of materials and assembly processes, can be used to properly design and implement avionic systems which can be expected to survive the operational environment induced stresses and strains; and can have long economic lifetimes that are virtually failure-free at the part level.

The references listed on Page IV-18 contain examples of the various models and equations which can be used in evaluating materials and processes used in developing new avionics systems. These same models and equations, when used for designing new avionics systems, could provide data and measurable parameters (related to physical life) which could be used in formulation of the economic life equation which could, in turn, be used to estimate the "true" economic life of the new system - assuming that the proper data base were established and maintained jointly by the USAF and the manufacturers/ integrators.

Ideally, each factor could be expressed as a measurable parameter (or set of parameters) and a model could be established which could be used to compute economic life from the parameters. This ideal is not readily achievable with the functional equation given previously. First, standard parameters for measuring the factors do not always exist (e.g., two engineers can usually agree that one system is more complex than another, but they do not use a common scale of complexity). Parts selection may have many relevant attributes, such as quality control during production, screening, testing, and derating which affect the evolving system differently. A second major problem is determining how the various factors are interrelated. For example, relationships could be additive, multiplicative, or exponential.

Given these above types of problems, it may be difficult to develop practical formulas with which to replace the generic equation shown above. Nevertheless, the concept of economic life can be a useful tool in the development of contractual and management activities that enable the USAF to better spend their resources; however, it requires more research before the exact nature of the model (or models) is known.

## 1.3 Economic Life and Life Cycle Cost Models

For a given avionics system, computation of economic life must include costs for design, development, production, operation, and support. These are the very factors that constitute life cycle cost (LCC). This observation, therefore, implies that LCC models can be used to support economic life analysis.

It should be emphasized that LCC and economic life are related but different concepts. LCC is defined as the total cost to acquire, maintain, and dispose of a system over its life. In this context, "life" can be defined in terms of the expected period of need for the mission served by the system, the expectations about technological or performance obsolescence, and/or historical precedents. A typical analysis question is: For a given system in a given scenario for a given number of years--what is the total cost? In LCC analysis, no attempt is made to define the life of the system in terms of cumulative costs, cost trends, or costs of alternatives.

Economic life, on the other hand, is concerned with alternatives to the given system and trends. The alternatives could include reacquisition of the same system after a number of years or replacement with a different design. Trends on such factors as labor rates, reliability, and spares/parts costs are of interest. If these trends are different for different architectures, parts standards, technologies, or other system factors, then they may affect how the costs of a given system compare to those of alternative systems. In other words, cost and reliability trends can impact economic life.

A candidate approach to implementing the economic life concept might be developed using LCC modeling. However, some revision would be required in order to use existing LCC models.

Existing LCC models can do a good job of capturing the development and acquisition costs of avionics systems. They can account for all factors that have significant influence on operating and support costs. Also, most LCC models allow for discounting and inflation factors.

Table IV-A-1 and Figure IV-A-1 in Appendix IV-A define the life-cycle-cost variables and relate the cost variables to the major elements of LCC for an avionics system in the context of a "spreadsheet" model. For a given system, an analyst can identify the subset of the elements that are relevant. By examining the column for each identified element, the analyst can identify the cost variables that apply. Equations that relate the cost variables to LCC can be taken from existing LCC models or can be readily derived.

Some modification will be necessary to apply this process during the development cycle. Early in the development process, when the initial goals are established, only limited cost information may be available on the design of the system. Rather than estimating the values of detailed cost variables, it may be more meaningful to estimate costs at higher levels of aggregation, and to estimate ranges of costs rather than exact points. As the development proceeds and more precise information becomes available, the estimate can be made more detailed and more accurate.

Existing LCC models can be used to evaluate economic tradeoffs between existing avionics and potential replacements. If the user specifies the number of years, then he can use a LCC model to compute the total cost to continue to operate the current avionics and the total cost to develop, field, and operate alternate equipment. By analyzing the rates of annual costs and the acquisition costs, he can compute the economic breakeven point.

With respect to economic life, this approach presents two difficulties. First, the analysis must account for cost trends such as increases in labor rates and increases in parts costs. The relative impact of a cost trend on avionics alternatives will vary. Second, economic life would be most useful if it is understood in terms of such factors as system architecture, reliability, parts selection, and technology. These factors are only indirectly included in existing LCC models.

A good analyst could work around these two difficulties. The chosen LCC model could be modified to accept different cost factors for each year of operation and support. The input data for each avionics alternative could be annotated to indicate how the input parameters are influenced by such factors as architecture, parts selection, and technology.

It could be useful to modify an existing LCC model to allow trend data and annotated input*. The selected LCC model should also satisfy the following requirements:

- User friendly (e.g., menu driven)
- Compatible with existing models (i.e., same variable names and quantities) and machines
- Well documented and portable
- Graphics and plotting capability.

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* One candidate for this model is the TI-59 programmable calculator LCC model. This model is well known, well documented, and straightforward to apply. However, it would have to be modified to handle data on factors that change over time. The current version of the TI-59 LCC model uses constant values for labor rates, parts costs, and reliability. One approach to handling trend data is to allow the user to choose the shape of the curve for an input data item from a set of "standard" curves. The user would then select the parameters that define where the curve lies. Another approach would allow the user to enter the data item as a different value for each year. The model could also be enhanced to produce graphics or plots. For example, it could print the curve of cumulative annual costs to highlight overall trends in using the system under study.

To support use of such a model, input data on trends would have to be identified. This may require an extensive data collection effort and/or analysis of historical data.

If the appropriate data can be collected or estimated, then a LCC model could be used to compare alternatives and to make inferences about economic life considerations.

## 1.4 Contractual Economic Life Measure (CELM)

Currently, the USAF is incurring high system support costs for some avionics systems. Past cost trends have shown that annual system support costs for avionics systems increase as these systems age. Consequently, the USAF is seeking the development of a method to eliminate or reduce the probability of incurring unacceptably high avionics system support costs in the future. One potential solution to this problem is that of a contractual nature in which the economic life of a system is specified by the contractor during the acquisition process. Ultimately, the estimated economic life would be considered by the USAF as one of many measures of merit upon which a contract might be awarded. Once awarded, the contractor would be responsible for ensuring that the estimated economic life of the proposed system is met (assuring that the appropriate incentives were available to support this responsibility).

### 1.4.1 CELM Definition

A contractual definition of economic life is a definition that can be used to specify the product to be delivered by the contractor. The requirements of a definition to meet this criterion are that it be:

- Precise (specifiable)
- Measurable (priceable)
- Deliverable.

The CELM definition must be precise (i.e., exactly or concisely defined) to provide the contractor(s) with a thorough and clear understanding of the concept, its use, and the contractor's responsibilities. It must be measurable to enable the USAF to compare alternative systems in the acquisition process and to objectively analyze the extent to which the contractor is meeting his estimate of the economic life of the system in the operational phase. It also must be deliverable. That is, it must be based only on those factors the contractor controls or influences, thereby protecting the contractor from being responsible for those factors outside his control which may alter his system's estimated economic life.

## 1.4.2 Contractor Responsibilities and Issues

Those factors of a system or design process that the contractor influences or has responsibility for are:

- System architecture
- Environmental assessment
- Parts selection
- Assembly
- Packaging
- Test and evaluation.

Several relevant observations can be made:

- Further effort is required to determine what parameters to use to measure these factors. Selected parameters for each measure should be linearly ordered.
- The above factors may act as bounds. For example, a given system architecture may limit the economic life of the system but may fail to guarantee that the other factors are realized in a manner that achieves the same or greater economic life.

System architecture, environmental factors, parts selection, assembly, packaging, and test and evaluation all have impacts on the system mean time between failures (MTBF), mean time between demands (MTBD), mean time between removals (MTBR), and mean time to repair (MTTR). In terms of economic life, one of the most important of these is parts selection. Although somewhat constrained by quality parts lists, parts selection continues to be a driving force in systems support costs. Numerous historical examples exist in which annual systems support costs have become unacceptably high as a result of parts having to be special-ordered. The use of transistors in the F106 radar system and the use of vacuum tubes in B52 avionics are two notable examples. Special-ordering of parts is often a result of the use of new technological developments which replace the technology used in the existing system. As new technology continues to replace that used in the past, replacement parts for the older system may become difficult and expensive to obtain. This discussion does not imply that new technology should be avoided. It does indicate a need for planned introductions of new technology.

Under a contractual economic life obligation, the contractor could be held accountable for excessive parts cost incurred as a result of the unavailability of spares in the marketplace. This could be accomplished by having the contractor guarantee in the contract that prices for parts will not exceed specified limits; hence ensuring the development of comprehensive and fair price limits. Computation of the limits could include factors for inflation and other factors not under the control of the contractor.

Use of parts price limits would require the contractor to assess candidate technologies in the design phase. For each technology, the contractor would have to ask questions such as the following:

- Are there any current or expected efforts to upgrade the technology?
- What is the current rate of usage of the technology in new systems?
- Is that rate increasing or decreasing?
- If components using the technology become unavailable for standard sources, what alternatives would exist?
- What is the expected life of the system being designed?

Assuming part price limits were developed, a practical question is: How would they be enforced? Such limits imply that the duration of the contract is the same as the economic life agreed on in the contract. Hence, any contract with less than a 10-year life may be acceptable.

Even if a formal contract to guarantee future prices cannot be used, the contractor can be required to perform analyses to examine expected and potential technology changes and their impact on support cost for the system he is designing. This could be done through an "economic life program" analogous to what is done today for reliability and maintainability. The elements of a potential economic life program are illustrated in Figure IV-1.4.2-1. Those elements which are candidates for consideration in an "economic life program" are:

- Inventory control/policy
- Levels of replacement for a system (i.e., parts, subassemblies, assemblies, etc.)
- Input/output specifications/engineering specifications.

Various approaches to inventory control could be analyzed by the contractor to examine their impacts on system support costs. For example, it may be more advantageous to stockpile various replacement parts as opposed to purchasing them when needed. A situation such as this may arise for a variety of reasons, one of which is the development of new technology. The development of new technology to replace a current technology often results in a major decrease in production of those parts necessary to sustain the current technology. Parts production dwindles and ultimately ceases. However, a demand continues to exist which must be satisfied by an insufficient supply; hence, unacceptably high costs result. Stockpiling of parts prior to a critical situation such as this may significantly reduce support costs and extend economic life. Figure IV-1.4.2-2 illustrates this concept of stockpiling inventory and its potential effects on system support costs throughout the system's life cycle.

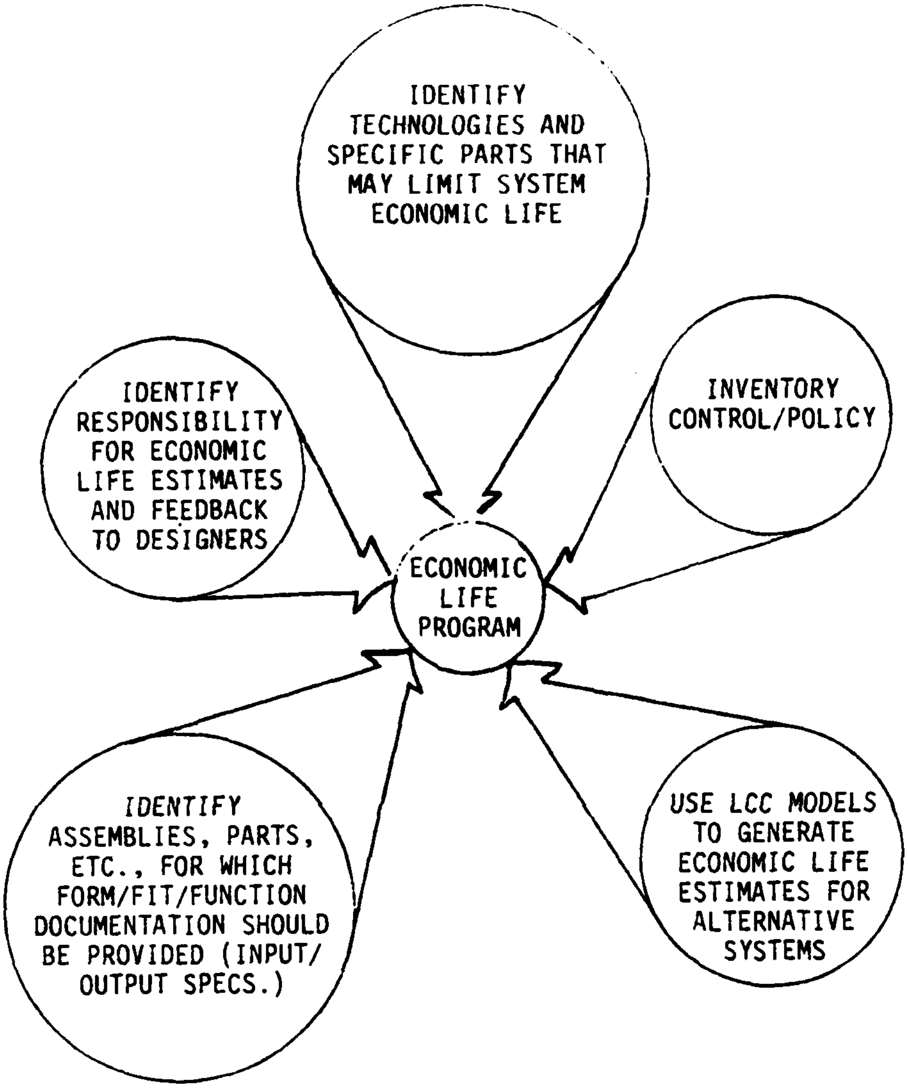
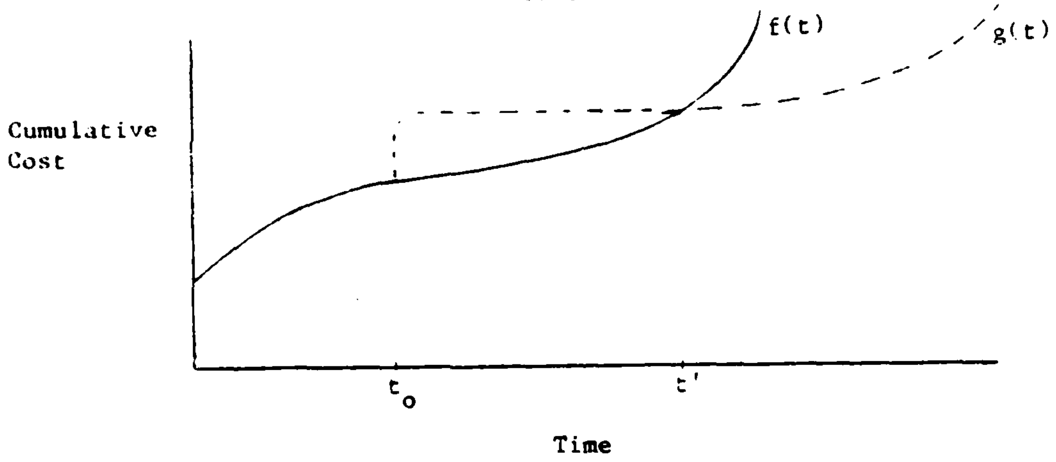



FIGURE IV-1.4.2-1. Potential Economic Life Program




- f(t) is the cumulative life cycle cost curve for system "X" where stock is acquired as needed.

- g(t) is the cumulative life cycle cost curve for system "X" where stock is acquired as needed until time "$t_o$" at which time a specified quantity is purchased and stockpiled.

**FIGURE IV-1.4.2-2. Stockpiling Inventory and Cumulative Life Cycle Cost**

From this figure, issues concerning the economic life of this system can be discussed. If the economic life of the system occurs before t', stockpiling inventory plays no role in extending the economic life of the system. However, if the economic life measure is greater than t', the use of stockpiling inventory is a viable means by which to extend the system's economic life.

Recall that the definition of economic life has been restricted to be a measure which addresses only those quantitative costs related to the economics of the life cycle cost of systems. In Figure IV-1.4.2-2, the cost curve, g(t), falls below that for f(t) for every point in time greater than t'. For equivalent cost, g(t) can sustain operation longer than f(t) at any time greater than t' hence resulting in a greater economic life. Other inventory control alternatives should also be analyzed to determine their effects on support costs and economic life of preliminary system designs.

Cost comparisons for the various replacement levels (i.e., piece parts, subassemblies, and assemblies) for preliminary system designs should be addressed as part of an overall "economic life program". The design of a system in which piece parts can be replaced as opposed to replacement of an entire subassembly or assembly could have a significant effect on system support costs.

The benefits derived from the analyses previously discussed in accordance with an "economic life program", specifically,

- Examination of technological change on system support costs
- Inventory control effects on system support costs
- Cost comparisons for various levels of replacement for systems,

will only be recognized when such analyses are done seriously as a team/cooperative effort as opposed to "check off the box" exercises. Tools which may be useful in performing such analyses are spread sheet packages, life cycle cost models, and forecasting models. The responsibility for the success of these analyses rests with the USAF and their ability to convey the importance of these analyses to the contractors and provide them with adequate incentive and guidance to perform them. Based on this discussion, it is suggested that DoD initiate the development of a guidance document that would provide the guidance necessary to perform these analyses.

Thus far, the issues pertaining to an "economic life program" have been discussed with respect to pre-contract award/RFP requirements. One requirement which should be part of the contractual agreement itself concerns the delivery of the final, "as built", engineering specifications. Stated in the contract should be a clause which requires the submission of these specifications (in terms of a re-procurement package) to the USAF upon completion of the production process of a system. This would provide the USAF with the information necessary to produce, alter, troubleshoot, or otherwise sustain operation of the system should the contractor be unable or unwilling to perform these services prior to or upon completion of his contractual obligation. Furthermore, if the USAF would find it cost-effective to acquire spares from another contractor, the requirements for the spares would be readily available.

### 1.4.3 USAF Responsibilities and Issues

Some of the aspects of a system or design process that the USAF influences or has responsibility for are:

Those activities that occur during the acquisition phase

- Estimation of desired/expected life of a system
- Specification of the LCC requirement (i.e., design to LCC)
- Definition of economic life measure
- Writing of RFP
- Release of RFP
- Evaluation of contractor proposals
- Confirmation of parameter goals that affect economic life factors
- Awarding of the contract

Those activities that occur during the operational phase

- Monitoring of the CELM for the system
- Approval of "paper design" including estimation of achievable reliability/maintainability/availability, etc., integrity parameters
- Approval of detailed design including planned integrity parameter values
- Approval of prototype system, reliability, growth estimates, etc.

An economic life measure (ELM) for contractual application must be compatible with the acquisition process. The USAF must define the ELM in the RFP. To do this, the desired (or expected) life of the system must be estimated. Desired system life should be a comprehensive estimate encompassing current and projected economic factors, anticipated technology changes, mission requirements, and the life of the host aircraft. The ELM must be specifiable, priceable, and deliverable if it is to form the basis of a contractual clause. The RFP should indicate how the ELM will be used in determination of the contract award.

The contractors' proposals would include estimates of the ELM for their proposed system designs. The ELM estimates may include or be supported by estimates of annual support cost and life cycle cost. It might be appropriate for the RFP to provide standard system utilization rates and labor rates for those cost estimates. In making the contract award, the USAF might choose to negotiate the ELM.

As the contractor performs the design, he should be motivated by the ELM contract clause to include anticipated economic and component availability factors in his design decisions.

After the system is fielded, the USAF must monitor the ELM for the system. The monitoring should be documented so that it can be examined by the contractor. Documentation is required to avoid contractual disputes. The descriptors of the ELM should be defined so that actual conditions of use can be compared to the conditions specified in the contract.

Table IV-1.4.3-1 summarizes the above activities.

### 1.4.4 Economic Life and Contractual Award

The USAF RFP should indicate to prospective contractors how the ELM will be used in determination of the contract award. This could be done in a variety of ways, one of which would require the development of a military standard or guidance document. The guidance document would then be referenced in RFP for use by contractors when preparing proposals. The guidance document should include:

TABLE IV-1.4.3-1. ECONOMIC LIFE MEASURE (ELM) IN THE ACQUISITION PHASE

| Phase | Action |
|---|---|
| USAF prepares RFP | Estimate desired system life ELM as award Ceiling for repair cost? |
| Release RFP | -- |
| Contractor responses | Predicted LCC<br>Predicted Annual Support Cost<br>Predicted Repair Cost |
| USAF selects winner | Negotiate ELM factors |
| Contractor builds system | LCC estimates<br>Repair cost estimate<br>.<br>.<br>. |
| Delivery | -- |
| Support | Measure ELM |

- Definition of economic life
- Economic life issues
- Economic life measures
  - Contractual (CELM)
  - Management (MELM)
- Usefulness of economic life estimates
- Procedures for estimating economic life
- Explanation of economic life and its role in contractual award.

The role of economic life in contractual award might consist purely of a weighting scheme in which the contractor's estimates of the cost incurred for a system up to its economic life and the number of years/time frame involved are evaluated with respect to USAF estimates of cost and time. The USAF estimates would be based on a previously established baseline system to

enable comparison of a wide range of proposed systems to one baseline system. This would allow unbiased comparisons and would provide a means that could be used to directly compare competing systems on their respective economic life merits.

The above discussion concerning the development of a DOD guidance document and the role of economic life in contractual award is not intended to be construed as the solution to the economic life issue. Further effort in this area is required and specific studies must be completed before any process for incorporating economic life into contractual efforts can be considered as a viable supplement to the current USAF acquisition and planning processes. A rigorous definition of economic life must be developed. Also, issues concerning fairness to competing contractors must be addressed, examined, and resolved before development of an economic life program can be substantiated. For example, definition of terms and assumptions used in a potential economic life program must be developed such that competing contractors' estimates of specific quantities are based on the same baseline and can be directly compared on a one-to-one basis. The matrix of costs/variables in Appendix A may be of value in this task if a baseline model is established and used as a "yardstick" for the evaluation.

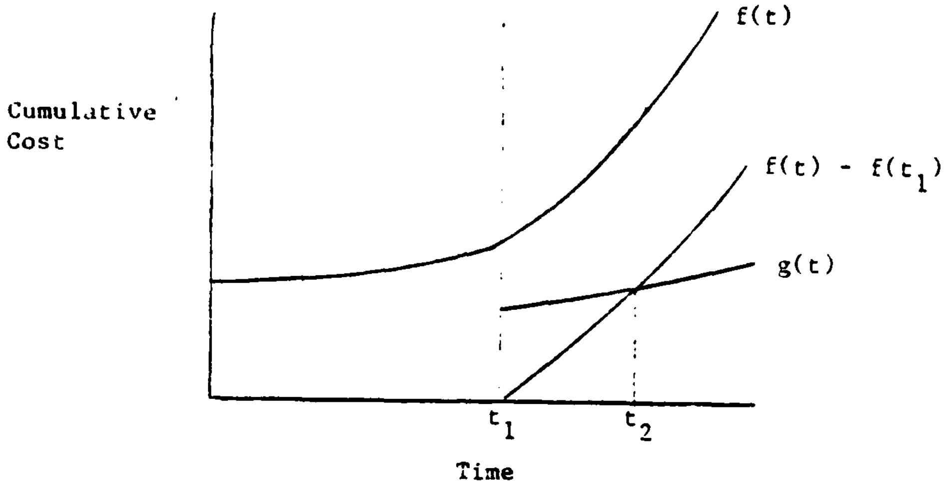
## 1.5 Management Economic Life Measure (MELM)

Aside from contractual applications, economic life measures have specific management applications. As a management tool, they could be used by the USAF to compare various technological opportunities. An illustration of the use of economic life measures in this manner is presented in Figure IV-1.5-1. Management could also use economic life measures to identify decision points/break points for current and projected systems. This would provide them with a tool to aid in the process of planning for and acquiring new systems by helping to identify those points in time when operation of current/projected systems is no longer economically feasible.

A critical component of the economic life concept is the recognition that it alone does not constitute the basis on which continued or terminated operation of a system or implementation of a proposed new system is founded. The above discussions suggest that "useful life" of a system is the basis for such decisions. Consequently, it is felt that economic life is most effective when used in conjunction with the other parameters of "useful life" of which

- Mission life
- Technological life
- Physical life
- Performance measures/criteria
- Environmental factors

are included.




- Original system acquired in year 0 for a cost of f(0)
- f(t) = cumulative cost of original system through year t
- Consider the alternatives available at year $t_1$. Once the system reaches year $t_1$, the preceding costs for the original system are considered "sunk" costs. The expected remaining costs for the original system are given by the curve $f(t) - f(t_1)$. The curve g(t) represents the costs to acquire a replacement system in year $t_1$, and to support that system. Year $t_2$ is the "crossover point" of the original system and the replacement system; i.e.,

$$g(t_2) = f(t_2) - f(t_1)$$

  and the time period $(t_2-t_1)$ is the remaining economic life of the original system.

(Note: The above curves should include discount factors.)

**FIGURE IV-1.5-1. A Conceptual View of Economic Life**

For economic life to be a useful tool for USAF management in identifying decision points/break points for current or proposed systems, a model for computing economic life must be established. Potential inputs for the model are:

- Contractor's prediction of economic life of the system
- Historical data for the system or similar systems
  - Failures
  - Failure rates
  - Environmental stress levels encountered
  - Maintenance level required
  - Operational stresses
- Technology projections
- Life cycle cost projections.

## 1.6 Conclusions and Recommendations

This report has presented a broad discussion of economic life and associated issues. A candidate definition of economic life was formulated. It was found to be useful in explaining the concept, but it did not lead directly to a precise, measurable quantity.

Existing life cycle cost models can be used for a variety of economic analyses, including determination of the "breakeven" point for some system comparisons. However, the models do not account for trends in operating and support cost factors and they do not show a direct relationship between costs and factors such as system architecture, environmental stresses, parts selection, complexity, and technologies used.

A conceptual formula for economic life was presented. This formula indicated the factors that are expected to be important in determining the economic life of an avionics system. These factors include system architecture, environmental stresses, complexity, parts selection, technologies used, repair characteristics, and the costs of alternative systems. Economic life is thus seen to be affected by system characteristics and by factors exogenous to the system, namely, technology changes, alternative systems availability/costs, and changing labor/supply costs.

This understanding was used as the basis for discussing economic life measures for contractual purposes and USAF management purposes. While there is still some reason to doubt the feasibility of developing a precise, specifiable measure of economic life, there are several activities that could be combined to develop an economic life program. Therefore, based on this report, it is recommended that further effort be expended to address the following issues:

- Technology prediction. Understanding of technology trends could be used to identify specific technologies that may either increase or decrease the economic life of a system.

- Engineering specifications. Certain assemblies or parts may experience sharp rises in replacement costs because they are no longer available as standard production items. For elements that may be susceptible to this phenomenon, the USAF could require engineering specifications in the form of a reprocurement package which specifies input/output requirements, from the original system contractor. These specifications could then be used to procure cost-effective replacements.

- Spares acquisition policies. Once an increasing cost trend for spares is identified, several actions are possible, including: initial purchase of a large quantity to support the remaining demand over the system life, development of a second source for the identical item, and/or development of a form-fit-function replacement that will have lower acquisition and operating costs. A methodology needs to be developed that will provide the basis for an economic comparison of these options.

## References

1. "Some Factors Affecting Leadless Chip Carrier Solder Joint Fatigue Life", Lake, J. K. and Wild, R. N., 28th National SAMPE Symposium, Disneyland Hotel, Anaheim, California, April 12-14, 1983 (pages 1406-1414).
2. "Design Guidelines for Random Vibration", Steinberg, D. S., Proceedings-Institute of Environmental Sciences, Designing Electronic Equipment for Random Vibration Environments, Los Angeles, California, March 25-26, 1982 (pages 13-15).
3. "Design for Long Fatigue Life in Random Vibration Environment," Medaglia, J. M., IBID (pages 25-35).

# APPENDIX IV-A

This appendix contains Table IV-A-1, which is a list of the possible input parameters that may need to be taken into consideration in the definition of the life-cycle-costs associated with the design, development and deployment of a new or updated avionics system.

This appendix also contains Figure IV-A-1 which is a matrix of the costs and variables which may be used to define parametric models associated with the life-cycle-costs of developing a new or updated avionics system. Using such a matrix, it is possible to identify those variables which are most likely to be capable of influencing the economic life costs associated with the life-cycle development process. A preliminary life-cycle-cost model has been constructed by relating specific variables to specific costs using "x's" to indicate the relationship of costs/variables. The placement of the "x's" represent "first-cut" models, which can be evaluated (assuming that the necessary data are available) using any of the conventional life-cycle-cost models. Since these cost/variables are presented in the context of a "spreadsheet", the analyst can play "what-if" and other sensitivity-type analyses to arrive at a **minimized cost model** for the particular avionics being developed.

The material in Table IV-A-1 and Figure IV-A-1 were obtained from a number of sources including specifically:

1. Life-Cycle-Cost Analysis of the Microwave Landing System Ground and Airborne System; Schust, A., Young, P., and Peter, K.; DOT/FAA/RD-81/96; October, 1981.

2. Evaluation of a Computer Aided Planning and Technology Assessment Process, Volume I; Brown, R.A., and Hitt, E.F., AFFDL-TR-73-16 Volume I; April, 1973.

3. The TRXTS TMS Life-Cycle-Cost Model; Neches, T.M., and Opstad, D.G.; The Assessment Group, January, 1980. (U.S. Navy Project).

Other sources are available in the literature and they should be researched to determine if there are additional costs/variables which can be added to the "spreadsheet" model.

TABLE IV-A-1. Life Cycle Cost Model - Definition of Terms

| | |
|---|---|
| AFHR | Average flight hours per month per aircraft |
| AMCOS | Amortization cost |
| AMHB | Average labor hours per maintenance action, base = program internal |
| AMHD | Average labor hours per maintenance action, depot = program internal |
| $AVALB_l$ | Availability of $l^{th}$ type base support equipment |
| $AVALB_m$ | Availability of $m^{th}$ type base support equipment |
| $AVALD_l$ | Availability of $l^{th}$ type depot support equipment |
| $AVALD_m$ | Availability of $m^{th}$ type depot support equipment |
| BETA | Base support equipment time available per month (hours) |
| BIT | Fraction of failures isolated to LRU by built-in test equipment |
| BLR | Base labor rate (dollars/hours) |
| $BMC_j$ | Average base materials cost per maintenance action on $j^{th}$ LRU |
| $BMCS_{j,k}$ | Average base materials cost per maintenance action on $k^{th}$ SRU in $j^{th}$ LRU |
| $BMH_j$ | Average labor hours to isolate $LRU_j$ failure to SRU level base |
| $BMH_m$ | Average labor hours to isolate $LRU_m$ failure to SRU level base |
| BMHS | Average labor hours to isolate failure to LRU, base |
| BMT | Average base turnaround time (months) |
| BSOB | Base SRU stocking objective (months) |
| BSOBL | Base LRU stocking objective (months) |
| BSOD | Depot SRU stocking objective (months) |
| BSODL | Depot LRU stocking objective (months) |
| $COND_j$ | Fraction $LRU_j$ failures resulting in condemnations |
| $CONDB_{j,k}$ | Fraction $SRU_{j,k}$ failures resulting in condemnations |
| CPP | Cost per page, original technical documentation |
| $CRFT_i$ | Number of aircraft receiving avionics in year i |

TABLE IV-A-1. (Continued)

| | |
|---|---|
| DELTA | Depot support equipment time available per month (hours) |
| DDAEH | Number of avionics engineering hours - detailed design |
| DDAEHC | Average cost avionics engineering hour - detailed design |
| DDFUC | Average cost of facilities use (CAD, etc.) - detailed design |
| DDMSH | Number of management/support hours - detailed design |
| DDPCP | Total cost of part/components program - detailed design |
| DDTH | Number of technician hours - detailed design |
| DDTHC | Average cost of technician hours - detailed design |
| DLR | Depot labor rate |
| $DMC_j$ | Average depot materials cost per maintenance action on $j^{th}$ LRU |
| $DMCS_{j,k}$ | Average depot materials cost per maintenance action on $k^{th}$ SRU in $j^{th}$ LRU |
| $DMH_j$ | Average labor hours to isolate $LRU_j$ faiflure to SRU level, depot |
| DMHS | Average labor hours to isolate failure to LRU level, depot |
| DMT | Depot turnaround time (months) |
| | |
| FOCB | Annual base facilities cost attributable to system being analyzed |
| FOCD | Annual depot facilities cost attributable to system being analyzed |
| FPM | Annual frequency of preventive maintenance |
| | |
| HOLDB | Average annual holding cost per item type, base |
| HOLDD | Average annual holding cost per item type, depot |
| | |
| IAMC | Cost of introducing each new inventory coded item |
| $ILRUB_j$ | Base sparing flag for $LRU_j$ |
| $ILRUD_j$ | Depot sparing flag for $LRU_j$ |
| INCOS | Installation cost of avionics in new aircraft |
| $ISRUB_{j,k}$ | Base sparing flag for $SRU_{j,k}$ |
| $ISRUD_{j,k}$ | Depot sparing flag for $SRU_{j,k}$ |
| $ITWL_j$ | Repair/throw-away flag for $j^{th}$LRU |
| $ITWS_{j,k}$ | Rapair/throw away flag for $SRU_{j,k}$ |

TABLE IV-A-1. (Continued)

| | |
|---|---|
| JSEB | Number of different types of base support equipment |
| JSED | Number of different types of depot support equipment |
| $LCOMB_l$ | Number avionics unit types to which $l^{th}$ type base support equipment is common |
| $LCOMB_m$ | Number avionics unit types to which $m^{th}$ type base support equipment is common |
| $LCOMD_m$ | Number avionics unit types to which $m^{th}$ type depot support equipment is common |
| $LCOML_j$ | Number avionics unit types to which $j^{th}$ LRU is common |
| $LCOMS_{j,k}$ | Number avionics unit type to which $SRU_{j,k}$ is common |
| $LMTBF_j$ | Mean time between failures (MTBF) of $j^{th}$ LRU |
| $LMTTR_j$ | Mean time to repair $LRU_j$ |
| $LUCOS_j$ | Unit cost of $j^{th}$ LRU |
| MINB | Minimum number of each type LRU spare |
| MINBP | Minimum number repair personnel per base |
| MINDP | Minimum number repair personnel per depot |
| MINSEB | Minimum number support equipment sets per type per base |
| MINSED | Minimum number support equipment sets per type per depot |
| MSEBO | Minimum annual support equipment operating cost, base |
| MSEDO | Minimum annual support equipment operating cost, depot |
| NAV | Average number avionics units per aircraft |
| NIC | Fraction of inventory coded items that are new |
| NLRU | Number LRU's per avionics unit |
| $NNAC_i$ | Number of new aircraft per year |
| $NOB_i$ | Number of bases in year i |
| $NOD_i$ | Number of depots in year i |
| NIOB | Number different item types stocked at base |

TABLE IV-A-1. (Continued)

| | |
|---|---|
| NOID | Number different item types stocked at depot |
| NPBD | Number pages base level documentation |
| NPDD | Number pages depot level documentation |
| $NRAC_i$ | Number of aircraft retrofitted in year i |
| $NSPBR_{j,k}$ | Number of $SRU_{j,k}$ spares purchased prior to year i |
| $NSPRL_j$ | Number of $LRU_j$ spares purchased prior to year i |
| $NS_i$ | Number of systems in operation in year i = program internal |
| $NSRU_j$ | Number of SRU's in $j^{th}$ LRU |
| | |
| OFAC | Average time to complete off-aircraft maintenance records |
| ONAC | Average time to complete on-aircraft maintenance records |
| OSB | Average SRU order/ship time, base (months) |
| OSBL | Average LRU order/ship time, base (months) |
| OSD | Average SRU order/ship time, depot (months) |
| OSDL | Average order/ship time, LRU, depot (months) |
| | |
| PACK | Packaging factor (packed weight/unpacked weight) |
| PDAEH | Number of avionics engineering hours - preliminary design |
| PDAEHC | Average cost - avionics engineering hours - preliminary design |
| PDFUC | Average cost of facilities use - preliminary design |
| PDMSH | Number of management/support hours - preliminary design |
| PDTH | Number of technician hours - preliminary design |
| PDMSHC | Average cost of management/support hours - preliminary design |
| PDTH | Number of technician hours - preliminary design |
| PDTHC | Average cost of technician hours - preliminary design |
| PFHR | Peak flight hours per month per aircraft |
| PMB | Available hours per year per man, base |
| PMD | Available hours per year per man, depot |
| PMMH | Average labor hours per preventive maintenance action |
| PRFUC | Average cost per unit produced - facilities use |

TABLE IV-A-1. (Continued)

| | |
|---|---|
| PRIC | Average cost per unit produced - inspection |
| PRM/SC | Average cost per unit produced - management/support |
| PRODB | Productivity of base repair personnel |
| PRODD | Productivity of depot repair personnel |
| PRPAC | Average cost per unit produced - parts |
| PRPEC | Average cost per unit produced - people |
| PRPKC | Average cost per unit produced - packaging |
| PRPRC | Average cost per unit produced - process |
| PRRDC | Average cost per unit produced - reliability demonstration |
| PRSHC | Average cost per unit produced - shipping |
| PRT/EC | Average cost per unit produced - test and evaluation |
| | |
| RICOS | Retrofit cost of avionics |
| $RMHB_j$ | Average labor hours to remove and replace $LRU_j$, base |
| $RPLB_j$ | Fraction $LRU_j$ failures repaired at base |
| $RTS_j$ | Fraction $LRU_j$ failures isolated to SRU at base |
| $RTSB_{j,k}$ | Fraction repairable $SRU_{j,k}$ repaired at base |
| RTSS | Fraction of failures isolated to LRU at base |
| | |
| SECOB | Support equipment operating cost, base |
| SECOD | Support equipment operating cost, depot |
| SHC | Shipping rate, first destination |
| $SMTBF_{j,k}$ | Mean time between failures of $k^{th}$ SRU in $j^{th}$ LRU |
| $SMTTR_{j,k}$ | Mean time to repair $SRU_{j,k}$ |
| SSHC | Shipping rate between base and depot |
| STR | Average time to complete supply transaction records |
| $SUCOS_{j,k}$ | Unit cost of $SRU_{j,k}$ |
| SUF(2) | LRU spares sufficiency factor |
| SUF(3) | SRU spares sufficiency factor |

TABLE IV-A-1. (Continued)

| | |
|---|---|
| TBMH | Total average base labor hours required to isolate LRU failure to SRU level |
| TCOSB | Training cost per base repair person |
| TCOSD | Training cost per depot repair person |
| TDMH | Total average depot labor hours required to isolate LRU failure to SRU level |
| T/EDAS | Cost of data acquisition system for test and evaluation |
| T/EDRC | Cost of data reduction |
| T/EESS | Cost of environmental stress screen program (components/modules/subassemblies) |
| T/EFUC | Cost of facilities use |
| T/EPSC | Cost of prototype system (parts, labor, process) |
| T/ESEH | Number of support engineering hours |
| T/ESEHC | Cost of support engineering hours |
| T/ETAF | Cost of test-analysis-fix (parts, labor, process) program |
| T/ETCBI | Cost of burn-in program (components/module/subassemblies) |
| TFR | Average time to complete transportation forms |
| TIC | Total number of inventory coded items in stock |
| TRB | Personnel turnover rate, base |
| TRD | Personnel turnover rate, depot |
| | |
| UNTBF | Mean time between failure of avionics unit |
| $USECOB_1$ | Unit cost of $1^{th}$ type base support equipment |
| $USECOB_m$ | Unit cost of $m^{th}$ type base support equipment |
| $USECOD_1$ | Unit cost of $1^{th}$ type depot support equipment |
| $USECOD_m$ | Unit cost of $m^{th}$ type depot support equipment |
| $UTILB_1$ | Utilization rate, $1^{th}$ type base support equipment |
| $UTILB_m$ | Utilization rate, $m^{th}$ type basse support equipment |
| $UTILD_1$ | Utilization rate, $1^{th}$ type depot support equipment |
| $UTILD_m$ | Utilization rate, $m^{th}$ type depot support equipment |

TABLE IV-A-1. (Continued)

| | |
|---|---|
| $WT_j$ | Weight of $j^{th}$ LRU (pounds) |
| $WTB_{j,k}$ | Weight of $k^{th}$ SRU in $j^{th}$ LRU (pounds) |
| XMINB | Minimum number each type SRU spares per base |

| VARIABLES | 1.0 ACQUISITION COSTS | 1.1 DESIGN AND DEVELOPMENT COSTS | 1.2 SYSTEM TEST AND EVALUATION COSTS | 1.3 PRODUCTION COSTS | 2.0 INSTALLATION COSTS | 3.0 LOGISTIC SUPPORT COSTS | 3.1 INITIAL AND REPLACEMENT SPARES | 3.2 ON-AIRCRAFT MAINTENANCE | 3.3 OFF-AIRCRAFT MAINTENANCE | 3.4 INVENTORY ENTRY AND SUPPLY MANAGEMENT | 3.5 SPECIAL SUPPORT EQUIPMENT | 3.6 TRAINING | 3.7 DATA MANAGEMENT AND TECHNICAL DOCUMENTATION | 3.8 FACILITIES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AFHR | | | | | | | X | X | X | | | X | | |
| AMCOS | X | | | | | | | | | | | | | |
| AMHB | | | | | | | | | | | | X | | |
| AMHD | | | | | | | | | | | | X | | |
| $AVALB_{l \text{ or } m}$ | | | | | | | | | | | X | | | |
| $AVALD_{l \text{ or } m}$ | | | | | | | | | | | X | | | |
| BETA | | | | | | | | | | | X | | | |
| BIT | | | | | | | X | | X | | | X | | |
| BLR | | | | | | | | | X | | | | | |
| $BMC_j$ | | | | | | | | | X | | | | | |
| $BMCS_{j,k}$ | | | | | | | | | X | | | | | |
| $BMH_{j \text{ or } m}$ | | | | | | | | | | | X | X | | |
| BMHS | | | | | | | | | | | | X | | |
| BMT | | | | | | | X | | | | | | | |
| BSOB | | | | | | | X | | | | | | | |
| BSOBL | | | | | | | X | | | | | | | |
| BSOD | | | | | | | X | | | | | | | |
| BSODL | | | | | | | X | | | | | | | |
| $COND_j$ | | | | | | | X | | X | | | | | |
| $CONDB_{j,k}$ | | | | | | | X | | X | | | | | |
| CPP | | | | | | | | | | | | | X | |
| $CRFT_i$ | | | | | | | X | | | | | | | |
| DELTA | | | | | | | | | | | X | | | |
| DDAEH | | X | | | | | | | | | | | | |
| DDAEHC | | X | | | | | | | | | | | | |
| DDFUC | | X | | | | | | | | | | | | |
| DDMSH | | X | | | | | | | | | | | | |
| DDMSHC | | X | | | | | | | | | | | | |
| DDPCP | | X | | | | | | | | | | | | |
| DDTH | | X | | | | | | | | | | | | |
| DDTHC | | X | | | | | | | | | | | | |

FIGURE IV-A-1. Life Cycle Cost Model - Matrix of Costs/Variables Used to Define Parametric Models

| VARIABLES | 1.0 ACQUISITION COSTS | 1.1 DESIGN AND DEVELOPMENT COSTS | 1.2 SYSTEM TEST AND EVALUATION COSTS | 1.3 PRODUCTION COSTS | 2.0 INSTALLATION COSTS | 3.0 LOGISTIC SUPPORT COSTS | 3.1 INITIAL AND REPLACEMENT SPARES | 3.2 ON-AIRCRAFT MAINTENANCE | 3.3 OFF-AIRCRAFT MAINTENANCE | 3.4 INVENTORY ENTRY AND SUPPLY MANAGEMENT | 3.5 SPECIAL SUPPORT EQUIPMENT | 3.6 TRAINING | 3.7 DATA MANAGEMENT AND TECHNICAL DOCUMENTATION | 3.8 FACILITIES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DLR | | | | | | | | | X | | | | | |
| $DMC_j$ | | | | | | | | | X | | | | | |
| $DMCS_{j,k}$ | | | | | | | | | X | | | | | |
| $DMH_j$ | | | | | | | | | | | X | X | | |
| DMHS | | | | | | | | | | | | X | | |
| DMT | | | | | | | X | | | | | | | |
| FOCB | | | | | | | | | | | | | | X |
| FOCD | | | | | | | | | | | | | | X |
| FPM | | | | | | | | X | | | | | | |
| HOLDB | | | | | | | | | | X | | | | |
| HOLDD | | | | | | | | | | X | | | | |
| IAMC | | | | | | | | | | X | | | | |
| $ILRUB_j$ | | | | | | | X | | | | | | | |
| $ILRUD_j$ | | | | | | | X | | | | | | | |
| INCOS | | | | | X | | | | | | | | | |
| $ISRUB_{j,k}$ | | | | | | | X | | | | | | | |
| $ISRUD_{j,k}$ | | | | | | | X | | | | | | | |
| $ITML_j$ | | | | | | | X | | X | | | | | |
| $ITWS_{j,k}$ | | | | | | | X | | X | | | | | |
| JSEB | | | | | | | | | | | X | | | |
| JSED | | | | | | | | | | | X | | | |
| $LCOMB_{l \text{ or } m}$ | | | | | | | | | | | X | | | |
| $LCOMD_{l \text{ or } m}$ | | | | | | | | | | | X | | | |
| $LCOML_j$ | | | | | | | X | | | | | | | |
| $LCOMS_{j,k}$ | | | | | | | X | | | | | | | |
| $LMIBF_j$ | | | | | | | X | X | X | | | X | | |
| $LMTTR_j$ | | | | | | | | | X | | | X | | |
| $LOCOS_j$ | | | | | | | X | | | | | | | |

FIGURE IV-A-1. Life Cycle Cost Model - Matrix of Costs/Variables Used to Define Parametric Models (Continued)

| VARIABLES | 1.0 ACQUISITION COSTS | 1.1 DESIGN AND DEVELOPMENT COSTS | 1.2 SYSTEM TEST AND EVALUATION COSTS | 1.3 PRODUCTION COSTS | 2.0 INSTALLATION COSTS | 3.0 LOGISTIC SUPPORT COSTS | 3.1 INITIAL AND REPLACEMENT SPARES | 3.2 ON-AIRCRAFT MAINTENANCE | 3.3 OFF-AIRCRAFT MAINTENANCE | 3.4 INVENTORY ENTRY AND SUPPLY MANAGEMENT | 3.5 SPECIAL SUPPORT EQUIPMENT | 3.6 TRAINING | 3.7 DATA MANAGEMENT AND TECHNICAL DOCUMENTATION | 3.8 FACILITIES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MINB | | | | | | | X | | | | | | | |
| MINBP | | | | | | | | | | | | X | | |
| MINDP | | | | | | | | | | | | X | | |
| MINSEB | | | | | | | | | | | X | | | |
| MINSED | | | | | | | | | | | X | | | |
| MSEBO | | | | | | | | | | | X | | | |
| MSEDO | | | | | | | | | | | X | | | |
| NAV | X | | | | X | | X | | | | | | | |
| NIC | | | | | | | | | | X | | | | |
| NLRU | | | | | | | X | X | X | | | X | | |
| $NNAC_j$ | X | | | | X | | | | | | | | | |
| $NOB_j$ | | | | | | | X | | | X | X | X | X | X |
| $NOD_j$ | | | | | | | X | | | X | X | X | X | X |
| NOIB | | | | | | | | | | X | | | | |
| NOID | | | | | | | | | | X | | | | |
| NPBD | | | | | | | | | | | | | X | |
| NPDD | | | | | | | | | | | | | X | |
| $NRAC_j$ | X | | | | X | | | | | | | | | |
| $NSPBR_{j,k}$ | | | | | | | X | | | | | | | |
| $NSPRL_j$ | | | | | | | X | | | | | | | |
| $NS_j$ | | | | | | | X | X | X | | X | X | | |
| $NSRU_j$ | | | | | | | X | | X | | | X | | |
| OFAC | | | | | | | | | X | | | | | |
| ONAC | | | | | | | | | X | | | | | |
| OSB | | | | | | | X | | | | | | | |
| OSBL | | | | | | | X | | | | | | | |
| OSD | | | | | | | X | | | | | | | |
| OSDI | | | | | | | X | | | | | | | |

FIGURE IV-A-1. Life Cycle Cost Model - Matrix of Costs/Variables Used to Define Parametric Models (Continued)

| VARIABLES | 1.0 ACQUISITION COSTS | 1.1 DESIGN AND DEVELOPMENT COSTS | 1.2 SYSTEM TEST AND EVALUATION COSTS | 1.3 PRODUCTION COSTS | 2.0 INSTALLATION COSTS | 3.0 LOGISTIC SUPPORT COSTS | 3.1 INITIAL AND REPLACEMENT SPARES | 3.2 ON-AIRCRAFT MAINTENANCE | 3.3 OFF-AIRCRAFT MAINTENANCE | 3.4 INVENTORY ENTRY AND SUPPLY MANAGEMENT | 3.5 SPECIAL SUPPORT EQUIPMENT | 3.6 TRAINING | 3.7 DATA MANAGEMENT AND TECHNICAL DOCUMENTATION | 3.8 FACILITIES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PACK | | | | | | | | | X | | | | | |
| PDAEH | | X | | | | | | | | | | | | |
| PDAEHC | | X | | | | | | | | | | | | |
| PDFUC | | X | | | | | | | | | | | | |
| PDMSH | | X | | | | | | | | | | | | |
| PDMSHC | | X | | | | | | | | | | | | |
| PDTH | | X | | | | | | | | | | | | |
| PDTHC | | X | | | | | | | | | | | | |
| PFHR | | | | | | | | | | | X | | | |
| PMB | | | | | | | | | | | | X | | |
| PMD | | | | | | | | | | | | X | | |
| PMMH | | | | | | | | X | | | | | | |
| PRFUC | | | | X | | | | | | | | | | |
| PRIC | | | | X | | | | | | | | | | |
| PRM/SC | | | | | | | | | | | | | | |
| PRODB | | | | | | | | | | | | X | | |
| PRODD | | | | | | | | | | | | X | | |
| PRPAC | | | | X | | | | | | | | | | |
| PRPEC | | | | X | | | | | | | | | | |
| PRPKC | | | | X | | | | | | | | | | |
| PRPRC | | | | X | | | | | | | | | | |
| PRRDC | | | | X | | | | | | | | | | |
| PRSHC | | | | X | | | | | | | | | | |
| PRT/EC | | | | X | | | | | | | | | | |
| RICOS | | | | | X | | | | | | | | | |
| $RMHB_j$ | | | | | | | | X | | | | | | |
| $RTLB_j$ | | | | | | | | X | | | | X | | |
| $RTS_j$ | | | | | | | X | | X | | | X | | |
| $RTSB_{j,k}$ | | | | | | | | | X | | | X | | |
| RTSS | | | | | | | X | | X | | | X | | |

FIGURE IV-A-1. Life Cycle Cost Model - Matrix of Costs/Variables Used to Define Parametric Models (Continued)

| VARIABLES | 1.0 ACQUISITION COSTS | 1.1 DESIGN AND DEVELOPMENT COSTS | 1.2 SYSTEM TEST AND EVALUATION COSTS | 1.3 PRODUCTION COSTS | 2.0 INSTALLATION COSTS | 3.0 LOGISTIC SUPPORT COSTS | 3.1 INITIAL AND REPLACEMENT SPARES | 3.2 ON-AIRCRAFT MAINTENANCE | 3.3 OFF-AIRCRAFT MAINTENANCE | 3.4 INVENTORY ENTRY AND SUPPLY MANAGEMENT | 3.5 SPECIAL SUPPORT EQUIPMENT | 3.6 TRAINING | 3.7 DATA MANAGEMENT AND TECHNICAL DOCUMENTATION | 3.8 FACILITIES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SECOB | | | | | | | | | | | X | | | |
| SECOD | | | | | | | | | | | X | | | |
| SHC | | | | | | | | | X | | | | | |
| $SMTBF_{j,k}$ | | | | | | | X | | X | | | X | | |
| $SMTTR_{j,k}$ | | | | | | | | | X | | | X | | |
| SSHC | | | | | | | | | X | | | | | |
| STR | | | | | | | | | X | | | | | |
| $SUCOS_{j,k}$ | | | | | | | X | | | | | | | |
| SUF(2) | | | | | | | X | | | | | | | |
| SUF(3) | | | | | | | X | | | | | | | |
| TBMH | | | | | | | | | | | X | | | |
| TCOSB | | | | | | | | | | | | X | | |
| TCOSD | | | | | | | | | | | | X | | |
| TDMH | | | | | | | | | | | X | | | |
| T/EDAS | | | X | | | | | | | | | | | |
| T/EDRC | | | X | | | | | | | | | | | |
| T/EESS | | | X | | | | | | | | | | | |
| T/EFUC | | | X | | | | | | | | | | | |
| T/EPSC | | | X | | | | | | | | | | | |
| T/ESEH | | | X | | | | | | | | | | | |
| T/ESEHC | | | X | | | | | | | | | | | |
| T/ETAF | | | X | | | | | | | | | | | |
| T/ETCBI | | | X | | | | | | | | | | | |
| TFR | | | | | | | | | X | | | | | |
| TIC | | | | | | | | | | X | | | | |
| TRB | | | | | | | | | | | | X | | |
| TRD | | | | | | | | | | | | X | | |
| UMTBF | | | | | | | | | X | | X | X | | |
| $USECOB_{l\ or\ m}$ | | | | | | | | | | | X | | | |
| $USECOD_{l\ or\ m}$ | | | | | | | | | | | X | | | |
| $UTILB_{l\ or\ m}$ | | | | | | | | | | | X | | | |
| $UTILD_{l\ or\ m}$ | | | | | | | | | | | X | | | |

FIGURE IV-A-1. Life Cycle Cost Model - Matrix of Costs/Variables Used to Define Parametric Models (Continued)

| VARIABLES | 1.0 ACQUISITION COSTS | 1.1 DESIGN AND DEVELOPMENT COSTS | 1.2 SYSTEM TEST AND EVALUATION COSTS | 1.3 PRODUCTION COSTS | 2.0 INSTALLATION COSTS | 3.0 LOGISTIC SUPPORT COSTS | 3.1 INITIAL AND REPLACEMENT SPARES | 3.2 ON-AIRCRAFT MAINTENANCE | 3.3 OFF-AIRCRAFT MAINTENANCE | 3.4 INVENTORY ENTRY AND SUPPLY MANAGEMENT | 3.5 SPECIAL SUPPORT EQUIPMENT | 3.6 TRAINING | 3.7 DATA MANAGEMENT AND TECHNICAL DOCUMENTATIO | 3.8 FACILITIES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $WT_j$ | | | | | | | | | X | | | | | |
| $WTB_{j,k}$ | | | | | | | | | X | | | | | |
| XMINB | | | | | | | X | | | | | | | |

FIGURE IV-A-1. Life Cycle Cost Model - Matrix of Costs/Variables Used to Define Parametric Models (Continued)

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